ANNEX L: Ozone Depleting Substance Emissions

Ozone is present in both the stratosphere[1], where it shields the Earth from harmful levels of ultraviolet radiation, and at lower concentrations in the troposphere[2], where it is the main component of anthropogenic photochemical “smog”. Chlorofluorocarbons (CFCs) and other compounds that contain chlorine or bromine have been found to destroy ozone in the stratosphere, and are commonly referred to as ozone-depleting substances (ODSs). If left unchecked, ozone depletion could result in a dangerous increase of ultraviolet radiation reaching the earth’s surface. In 1987, nations around the world signed the *Montreal Protocol on Substances that Deplete the Ozone Layer*. This landmark agreement created an international framework for limiting, and ultimately eliminating, the use and emission of most ozone depleting substances, which are used in a variety of industrial applications, including refrigeration and air conditioning, foam blowing, fire extinguishing, aerosol propellants, sterilization, and solvent cleaning.

In the United States, the Clean Air Act Amendments of 1990 provide the legal instrument for implementation of the *Montreal Protocol* controls. The Clean Air Act classifies ozone depleting substances as either Class I or Class II, depending upon the ozone depletion potential (ODP) of the compound.[3] The production of CFCs, halons, carbon tetrachloride, and methyl chloroform–all Class I substances--has already ended in the United States. However, because stocks of these chemicals remain available and in use, they will continue to be emitted for many years from applications such as refrigeration and air conditioning equipment, fire extinguishing systems, and metered dose inhalers. As a result, emissions of Class I compounds will continue, in ever decreasing amounts, into the early part of the next century. Class II substances, which are comprised of hydrochlorofluorocarbons (HCFCs), are being phased-out at a later date because of their lower ozone depletion potentials. These compounds are serving as interim replacements for Class I compounds in many industrial applications. The use and emissions of HCFCs in the United States is anticipated to increase over the next several years. Under current controls, the production of all HCFCs in the United States will end by the year 2030.

In addition to contributing to ozone depletion, CFCs, halons, carbon tetrachloride, methyl chloroform, and HCFCs are also significant greenhouse gases. The total impact of ozone depleting substances on global warming is not clear, however, because ozone is also a greenhouse gas. The depletion of ozone in the stratosphere by ODSs has an indirect negative radiative forcing, while most ODSs have a positive direct radiative forcing effect. The IPCC has prepared both direct GWPs and net (i.e., combined direct and indirect effects) GWP ranges for some of the most common ozone depleting substances (IPCC 1996). Direct GWPs account for the direct global warming impact of the emitted gas. Net GWP ranges account for both the direct impact of the emitted gas and the indirect effects resulting from the destruction of ozone.

Although the IPCC emission inventory guidelines do not include reporting emissions of ozone depleting substances, the United States believes that no inventory is complete without the inclusion of these emissions. Emission estimates for several ozone depleting substances are provided in Table L-1.

Table L-1: Emissions of Ozone Depleting Substances (Gg)

Compound	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
Class I									

[1] The stratosphere is the layer from the top of the troposphere up to about 50 kilometers. Approximately 90 percent of atmospheric ozone lies within the stratosphere. The greatest concentration of ozone occurs in the middle of the stratosphere, in a region commonly called the ozone layer.

[2] The troposphere is the layer from the ground up to about 11 kilometers near the poles and 16 kilometers in equatorial regions (i.e., the lowest layer of the atmosphere, where humans live). It contains roughly 80 percent of the mass of all gases in the atmosphere and is the site for weather processes including most of the water vapor and clouds.

[3] Substances with an ozone depletion potential of 0.2 or greater are classified as Class I. All other substances that may deplete stratospheric ozone but which do not have an ODP of 0.2 or greater, are classified as Class II.

CFC-11	53.5	48.3	45.1	45.4	36.6	36.2	26.6	25.1	24.9
CFC-12	112.6	103.5	80.5	79.3	57.6	51.8	35.5	23.1	21.0
CFC-113	26.4	20.6	17.1	17.1	8.6	8.6	+	+	+
CFC-114	4.7	3.6	3.0	3.0	1.6	1.6	0.3	0.1	0.1
CFC-115	4.2	4.0	3.8	3.6	3.3	3.0	3.2	2.9	2.7
Carbon Tetrachloride	32.3	31.0	21.7	18.6	15.5	4.7	+	+	+
Methyl Chloroform	158.3	154.7	108.3	92.9	77.4	46.4	+	+	+
Halon-1211	1.0	1.1	1.0	1.1	1.0	1.1	1.1	1.1	1.1
Halon-1301	1.8	1.8	1.7	1.7	1.7	1.8	1.9	1.9	1.9
Class II									
HCFC-22	79.8	79.5	79.5	71.2	71.4	72.3	73.2	74.2	75.1
HCFC-123	+	+	0.3	0.3	0.5	0.6	0.7	0.8	0.9
HCFC-124	+	+	0.4	2.6	4.8	5.2	5.6	5.9	6.1
HCFC-141b	+	+	+	5.0	12.4	20.6	25.4	25.1	26.7
HCFC-142b	+	+	0.7	1.7	4.6	7.3	8.3	8.7	9.0
HCFC-225ca/cb	+	+	+	+	+	+	+	+	+

Source: EPA
+ Does not exceed 0.05 Gg

Methodology and Data Sources

Emissions of ozone depleting substances were estimated using two simulation models: the Atmospheric and Health Effects Framework (AHEF) and the EPA's Vintaging Model.

AHEF contains estimates of U.S. domestic use of each of the ozone depleting substances. These estimates were based upon data that industry reports to the EPA and other published material. The annual consumption of each compound was divided into various end-uses based upon historical trends and research into specific industrial applications. These end-uses include refrigerants, foam blowing agents, solvents, aerosol propellants, sterilants, and fire extinguishing agents.

With the exception of aerosols, solvents, and certain foam blowing agents, emissions of ozone depleting substances are not instantaneous, but instead occur gradually over time (i.e., emissions in a given year are the result of both ODS use in that year and use in previous years). Each end-use has a certain release profile, which gives the percentage of the compound that is released to the atmosphere each year until all releases have occurred. In refrigeration equipment, for example, the initial charge is released or leaked slowly over the lifetime of the equipment, which could be 20 or more years. In addition, not all of the refrigerant is ultimately emitted—some will be recovered when the equipment is retired from operation.

The AHEF model was used to estimate emissions of ODSs that were in use prior to the controls implemented under the *Montreal Protocol*. This included CFCs, halons, carbon tetrachloride, methyl chloroform, and HCFC-22. Certain HCFCs, such as HCFC-123, HCFC-124, HCFC-141b, HCFC-142b, HCFC-225ca and HCFC-225cb, have also entered the market as interim substitutes for ODSs. Emissions estimates for these compounds were taken from the EPA's Vintaging Model.

The Vintaging Model was used to estimate the use and emissions of various ODS substitutes, including HCFCs. The name refers to the fact that the model tracks the use and emissions of various compounds by the annual "vintages" of new equipment that enter service in each end-use. The Vintaging Model is a "bottom-up" model. Information was collected regarding the sales of equipment that use ODS substitutes and the amount of the chemical required by each unit of equipment. Emissions for each end-use were estimated by applying annual leak rates and release profiles, as in the AHEF. By aggregating the data for more than 40 different end-uses, the model produces estimates of annual use and emissions of each compound.

Uncertainties

Uncertainties exist with regard to the levels of chemical production, equipment sales, equipment characteristics, and end-use emissions profiles that are used by these models.